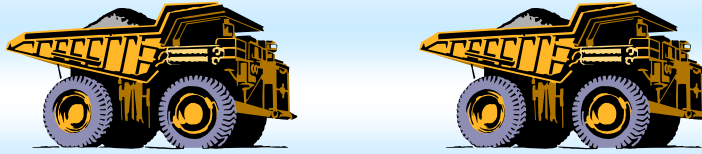


# Volumetric Tests

Qualified Aggregate Technician



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## Overview

- Volumetrics
- Specific Gravity
  - Different types
  - Uses
- Density
  - Why density?
- Unit Weight



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## What are Volumetrics?

- All matter has weight and occupies space
- Volumetrics are the relationships between weight and volume
- Asphalt and concrete mix designs are based on aggregate and mixture volumetrics



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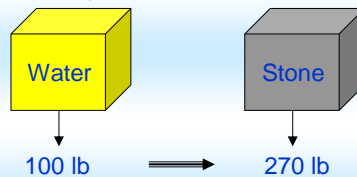
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## Specific Gravity

- **Ratio of aggregate weight to the weight of an equal volume of water**
  - Dimensionless number (no units attached)

Specific Gravity = 2.70 means that the rock weighs 2.70 times an equal volume of water



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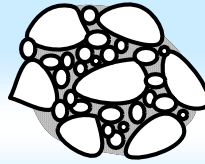
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## Uses of Specific Gravity

- Weight - Volume Conversions
- Hot Mix Asphalt Designs (BOD)
- Portland Cement Concrete Designs (SSD)
- Identifying Deleterious Materials (e.g. shale or chert)
- Mining Operations / Planning
- Quantity Calculations
- Void Calculations
- Float / Separation Systems



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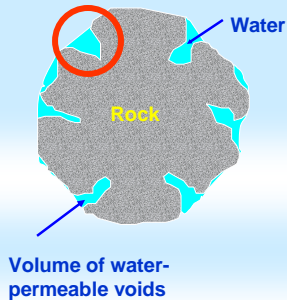
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## Rock and Water

Surface Voids



Considerations:

- 1) Rock has weight
- 2) Rock takes up space (volume)
- 3) Absorbed Water has weight
- 4) Absorbed Water takes up space (volume)

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## Specific Gravity

$$\text{Specific Gravity} = \frac{\text{Weight}}{\text{Volume} * (\text{Unit Weight of Water})}$$

$$G = \frac{W}{V\gamma}$$

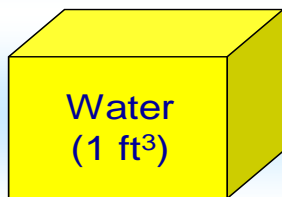
G=Specific Gravity  
W = Weight  
V=Volume  
 $\gamma$  = Unit Wt. Of Water

## Unit Weight of Water

$$\gamma_w = 1.000 \text{ g/cm}^3$$



1.000 g/cm<sup>3</sup>



62.4 lb/ft<sup>3</sup>

$$\gamma_w = 62.4 \text{ lb/ft}^3$$

## Types of Specific Gravity

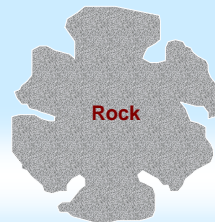
- Apparent
- Bulk Oven Dry (BOD)
- Bulk Saturated Surface Dry (SSD)



## Apparent Specific Gravity

Considerations:

- 1) Mass of Oven Dry Rock
- 2) Volume of Solid Rock Only

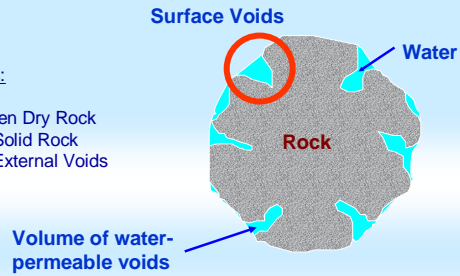


$$G_{sa} = \frac{\text{Mass of Oven Dry Aggregate}}{(\text{Volume of Oven Dry Aggregate}) \times (\text{Unit Weight of Water})}$$

## BOD Specific Gravity

Considerations:

- 1) Mass of Oven Dry Rock
- 2) Volume of Solid Rock
- 3) Volume of External Voids



$$G_{sb} = \frac{\text{Mass of Oven Dry Aggregate}}{(\text{Volume of Aggregate} + \text{Volume of Voids}) \times (\text{Unit Weight of Water})}$$

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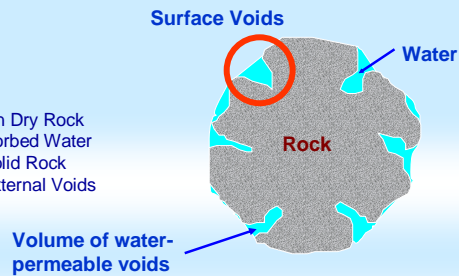


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## SSD Specific Gravity

Considerations:

- 1) Mass of Oven Dry Rock
- 2) Mass of Absorbed Water
- 3) Volume of Solid Rock
- 4) Volume of External Voids



$$G_{SSD} = \frac{\text{Mass of Oven Dry Aggregate} + \text{Mass of Absorbed Water}}{(\text{Volume of Aggregate} + \text{Volume of Voids}) \times (\text{Unit Weight of Water})}$$

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## Specific Gravity Relationships

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It is Always True that

**Apparent > SSD > BOD**

Unless

**Absorption = 0**

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## Specific Gravity Relationships

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**Apparent = SSD = BOD**

Only When

**Absorption = 0**

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## Coarse Agg Specific Gravity

- AASHTO T85
  - Dry aggregate
  - Soak in water for 15-19 hours
  - Decant water
  - Use towel to get SSD condition
  - Determine mass of SSD aggregate in bucket
  - Determine mass of aggregate under water
  - Dry to constant mass
  - Determine oven dry mass

## Soaking, Submerging Bucket, and Scale





## Achieve SSD Condition



## Calculate 3 Gravities From 1 Test

- A = mass oven dry
- B = mass SSD
- C = mass under water

$$\text{Apparent} = G_{sa} = A / (A - C)$$

$$\text{BOD} = G_{sb} = A / (B - C)$$

$$\text{SSD} = G_{SSD} = B / (B - C)$$

$$\text{Absorption \%} = [(B - A) / A] * 100$$

## Fine Agg. Specific Gravity

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- KM 64-605
  - Wash sample over a #200 sieve
  - Dry aggregate
  - Soak in water for 15 - 24 hours
  - Decant water over a #200 sieve
  - Spread out on plastic and dry to SSD with fan
  - Add 500 grams of SSD aggregate to pycnometer and 500 grams of SSD aggregate to a pan to be placed in an oven
  - Add water to 90 percent of pycnometer capacity and place on Gilson SS-28 vibrator for 4 minutes at high setting
  - Top off pycnometer with a bead of water and determine the mass of the pycnometer, aggregate and water
  - Determine mass of oven dry portion

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## Fine Agg. Specific Gravity

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## SSD Condition

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## Pycnometer & Vibrator

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## Calculate 3 Gravities From 1 Test

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- A = mass oven dry
- B = mass of pycnometer filled with water
- C = mass pycnometer, SSD aggregate and water
- S = mass SSD aggregate

$$\text{Apparent} = G_{sa} = A / (B + A - C)$$

$$\text{BOD} = G_{sb} = A / (B + S - C)$$

$$\text{SSD} = G_{SSD} = S / (B + S - C)$$

$$\text{Absorption \%} = [(S - A) / A] * 100$$

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## Specific Gravity Review

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- Commonly Used for Weight-Volume Conversions
- Essential in HMA and PCC Mix Designs
- 3 Gravities discussed
  - Apparent, BOD, SSD
  - 3 Gravities Calculated From 1 Test Procedure
- Apparent > SSD > BOD, except when Absorption=0  
Absorption of 0 is very rare

## Density

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- Density of an Aggregate is Defined as Weight per Unit Volume
  - Pounds per Cubic Foot = pcf = lb / ft<sup>3</sup>
  - Grams per Cubic Centimeter = gm / cc = gm / cm<sup>3</sup>
  - Tons/yd<sup>3</sup>, N/m<sup>3</sup>, lb/yd<sup>3</sup>, lb/in<sup>3</sup>, oz/in<sup>3</sup>, gm/mm<sup>3</sup>

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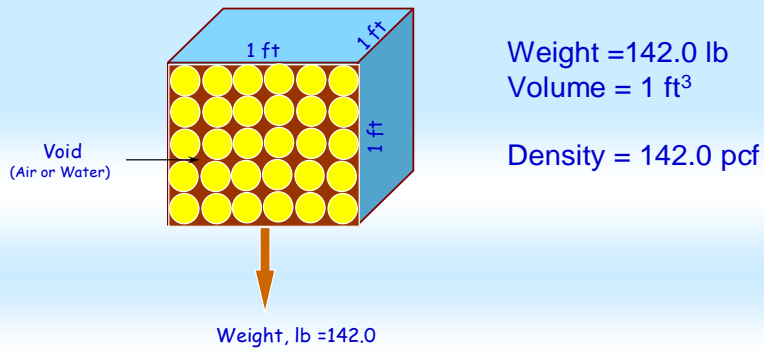
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## Volume

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- Volume is the Space Occupied by a substance
- 3-Dimensional Calculation
  - length x width x depth
- Unit Volume is the Space where length=width=depth=1 Unit

# Density



## Why Density?

- The purpose of Aggregate Base is to Provide Adequate Support
- Support is Measured by Strength and Stiffness
- Strength and Stiffness are Derived from Stone-to-Stone Contact in an Aggregate Support Layer
- Stone-to-Stone Contact Provides Internal Friction to Resist Particles Sliding Across Each Other
- Dry Density is a Measure of the Amount of Solid Particles (Weight) in a Unit Volume

## Why Density?

- Higher Density Indicates more stone-to-stone contact...
  - (except with high fines contents)
- More Stone-to-Stone Contact Means Greater Internal Friction...
- Greater Internal Friction Increases the Stiffness and Strength...
- *Increased Stiffness & Strength Provide Greater Structural Support in a Pavement System!!!*



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## What Influences Density?

- Gradation
- Moisture
- Compactive Effort
- Particle Shape and Others...



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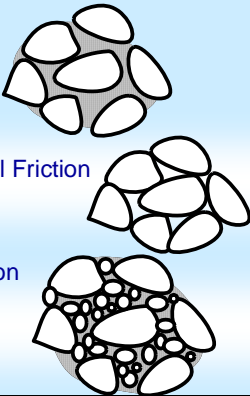
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# Gradation Influence

- Too Fine
  - Coarse Particles Float in Fines
- Too Coarse
  - Excessive Voids & Lower Internal Friction
- Just Right
  - Well-proportioned Size Distribution



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# Moisture Influences



- Too Wet
  - Base is “Soupy” & Water Pushes Particles Apart
- Too Dry
  - No Lubrication to Enhance Compaction
- Just Right
  - Particles Move Easier and Voids Replaced with Solid Particles

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## Compactive Effort

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- Too Little
  - Particles aren't Tightly Packed
- Too Much
  - Breakdown Particles, Generate Fines, Coarse Float in Fines Matrix

**GOOD  
COMPACTION  
LEADS TO  
GOOD  
PERFORMANCE**



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## Others...

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- Particle Shape
- Plasticity
- Construction Foundation



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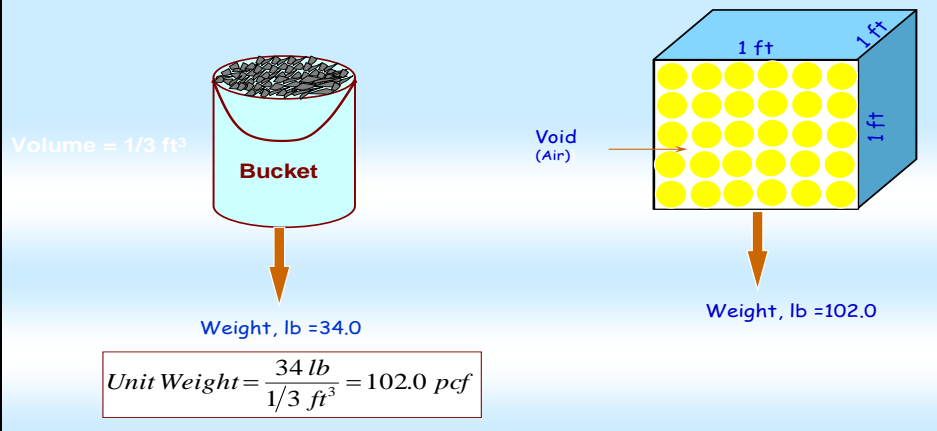
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## Unit Weight

- What is Unit Weight?
  - Density of material determined according to specified procedures
- Used for Concrete Mix Designs, Yields, Stockpile Inventories
- AASHTO T19
  - Dry Loose or Dry Rodded
  - 1/10-, 1/3-, 1/2-, 1-, 2 1/2-, or 3 1/2- ft<sup>3</sup> Bucket

## Unit Weight



## Voids Calculations

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- Void space can be calculated from the unit weight value if the bulk specific gravity is known

$$\%Voids = \frac{(G_{sb} * \gamma_w) - \gamma_s * 100}{G_{sb} * \gamma_w}$$

$G_{sb}$  = BOD Gravity

$\gamma_w$  = Unit Weight of Water =  $1 \text{ g/cm}^3 = 62.4 \text{ lb/ft}^3$

$\gamma_s$  = Unit Weight of Solid (stone)

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# Voids Calculations

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$$\%Voids = \frac{(G_{sb} * \gamma_w) - \gamma_s}{G_{sb} * \gamma_w} * 100$$

$$G_{sb} = 2.70$$

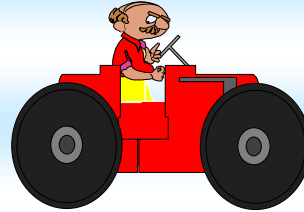
$$\gamma_w = \text{Unit Weight of Water} = 62.4 \text{ pcf}$$

$$\gamma_s = \text{Unit Weight of Stone} = 102.0 \text{ pcf}$$

$$\% Voids = \frac{(2.70 \times 62.4) - 102.0}{2.70 \times 62.4} \times 100 = 39.5\%$$

## Review - Density

- Higher Density Indicates more stone-to-stone contact... which leads to improved performance
- Factors influencing density
  - Gradation
  - Moisture Content
  - Compactive Effort
  - Construction Foundation
  - Particle Shape
  - Plasticity



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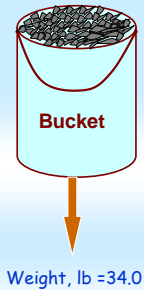
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## Review – Unit Weight

- Unit weight is a density measurement
- Unit Weight used in concrete mix designs, yield calculations, stockpile inventories...
- Voids can be calculated knowing unit weight and specific gravity of a material



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# Summary

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- Specific Gravity
  - Apparent, BOD, SSD
- Density
  - Factors influencing density
- Unit Weight



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